(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 May 2003 (08.05.2003)

PCT

(10) International Publication Number
WO 03/039133 A1

(51) International Patent Classification⁷: H04N 1/40

(21) International Application Number: PCT/US02/34876

(22) International Filing Date: 29 October 2002 (29.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/985,082 1 November 2001 (01.11.2001) US

(71) Applicant: HEWLETT-PACKARD COMPANY [US/US]; 3000 Hanover Street, M/S 1051, Palo Alto, CA 94304-1112 (US).

(72) Inventor: OBRADOR, Pere; 2309 Rock Street, #21, Mountain View, CA 94043 (US).

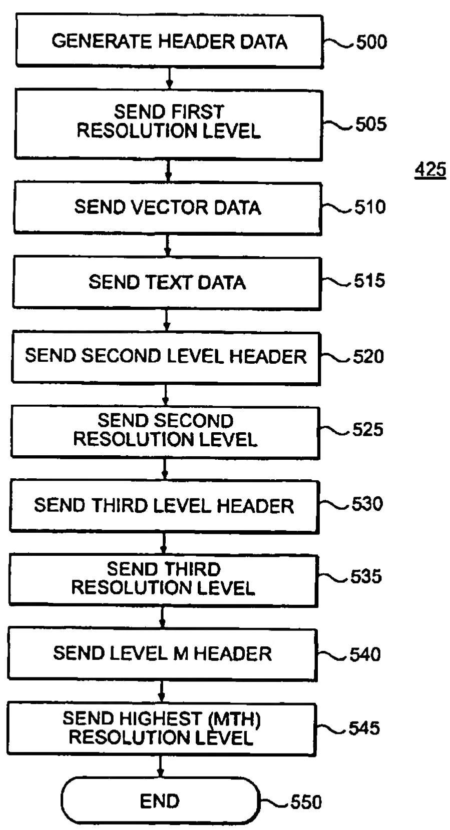
(74) Agent: HEMINGER, Susan, E.; Hewlett-Packard Company, IP Administration, P. O. Box 272400, Ft. Collins, CO 80527-2400 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK,

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR LOW MEMORY RENDERING



(57) Abstract: A method and an apparatus used, for example, in conjunction with a computer or similar device, provides for multi-resolution rendering of image data, where the image data includes background image data, vector data and text data, so as to accommodate memory capacities of rendering devices. The computer (22) may send image data in a multi-resolution format from the computer to one of several rendering devices (20, 40, 50, 60, 70). The multi-resolution format may be achieved by frequency domain coding (420) or generation of image swaths (410), or a combination thereof. The image data may first be sent (505) in a low resolution format, and a rendering device determines, based on its memory, whether the corresponding image or text should be rendered. Next, vector data (510) and/or text data (515) may be supplied to the rendering device. Then, higher resolution data may be sent (525, 535) after the text/vector date so as to maximize memory usage of the rendering device. Additionally, in a printing application, the image data may be divided into swaths (310), with each swath separately provided to a printer.

WO 03/039133 A1

TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND APPARATUS FOR LOW MEMORY RENDERING

Technical Field

The technical field is rendering images from an image data contained in a digital file.

Background

Rendering devices are used to generate an image based on input image data. The input image data may be digital data contained in a file that is stored in a memory, such as a memory associated with a personal computer. Rendering devices may take many forms, and may be portable or essentially fixed. Examples of rendering devices include a cellular telephone, a facsimile machine, a computer with a display, and a printer. The cellular telephone may receive data from a wireless telephone network and may render text and graphical images on a display screen. The facsimile machine may render images and text onto paper or other suitable media. The computer may receive and store the image data and may concurrently, or subsequently, render the image on the display. Printers may receive image data from an attached computer, and may store the image data prior to rendering. Rendering devices used in connection with personal computers, or other computers and similar devices, are capable of rendering images and text either as bit map data or line drawing images. Image data supplied to the rendering device may be photograph data from a digital camera, data generated by a computer graphics package, or simply text data generated, for example, by a word processing program. Printers used to render the image data may be large format printers capable of printing posters, architectural images, and other large images. The printers may also include more common laser printers and ink jet printers.

In the specific case of a printer, print data received by the printer from a computer may include bit map data specifying an image in the form of a bit map, vector data specifying features in terms of vectors, and text data specifying text characters. For example, an architect's printing requirements may include a background photograph showing a building site, and superimposed, a computer generated image of a building having rendered texture and tones. The architect's image may also contain arrows and text pointing to individual features on the building, with the arrows and text superimposed either over the computer generated image or the background photograph.

However, many rendering devices do not have enough memory capacity to store an entire image to be rendered. As a result, the image to be rendered may be rendered with data missing, such a broad white stripe running the length of the image, for example.

Summary

A rendering system used, for example, in conjunction with a computer or similar device, provides for multi-resolution rendering of image data, comprising background image data, vector data and text data, so as to accommodate memory capacities of rendering devices in the rendering system. The computer may send the image data in a multi-resolution format from the computer to one of several rendering devices coupled to the rendering system. Background image data may first be sent in a low resolution format, and the rendering device determines, based on a memory capacity of the rendering device, whether the corresponding image or text should be rendered. Next, vector data and/or text data may be supplied to the rendering device. In this way, the rendering device initially receives low resolution background image data together with vector data and text data for any vectors or text that overlay the image data. Finally, the computer sends refined image data in a high resolution format. In an embodiment, sending the high resolution image data may occur over several iterations, with each successive iteration providing higher resolution data.

In an embodiment, the rendering device is a printer that receives low resolution background image data followed by the vector data and/or the text data, and stores the received data in memory. Because the background image data is in a low resolution format, the printer does not need a large amount of memory to store the background image data along with the vector and/or text data. The printer then receives refined background image data in a high resolution format. Depending on the amount of available memory, the printer may store the refined, high resolution image data. In an embodiment, the printer accumulates higher resolution image data until the capacity of the printer's memory is reached, at which point the printer combines the lower resolution image data with the higher resolution image data in order to render the image. Depending on the printer memory, the highest resolution image file is stored, and printing of the image data includes the highest resolution image data. For printers having a lower memory capacity than that required to store the highest resolution image data, printing may proceed based on intermediate resolution image data, and any vector and/or text data.

In an alternative embodiment, and as applied to specific printer types, a printer driver in the computer may send the printer only as much print data as can be stored in the printer memory. In another embodiment, the computer may break the print data into a series of swaths or bands, with each swath representing a portion of the print data. A first

swath of the print data may include image data, vector data, and text data that would be printed in a specified height on a printing medium. For example, when printing on a standard 81/2 X 11 page, the first swath may represent the first two inches of the page. The print data for the first swath may be stored in the printer memory, and that portion of the print data may be used to print an image portion on the page. The print data are then discarded from memory, and the computer sends print data for the next swath to the printer. This process continues until the entire page is printed.

In yet another embodiment, the printer system uses a combination of printing by swaths, and multi-resolution printing within one or more of the swaths, to provide the highest possible image resolution and to maximize use of the printer memory.

Description of the Drawings

The detailed description will refer to the following drawings in which like numerals refer to like elements, and in which:

Figures 1a - 1b illustrate a system that uses multi-resolution rendering;

Figures 2a – 2c illustrate a conceptual model and process for multi-resolution coding to be used for low-memory rendering;

Figures 3a - 3c illustrate a relationship between image quality and bitmap transfer;

Figure 4 illustrates an alternative approach to low-memory rendering;

Figure 5 illustrates schematically an image data file; and

Figures 6 - 9 are flowcharts illustrating processes for low-memory rendering.

Detailed Description

Figure 1a illustrates a system 10 adapted for multi-resolution rendering as a solution for low-memory rendering devices. The system 10 includes an image data source 20, which may be a personal computer 22 or a wireless device 24, and a plurality of rendering devices, including a computer display 30, a laser printer 40, an ink jet printer 50, and a large format printer 60. The wireless device 24 and the personal computer 22 may communicate with any and all of the plurality of rendering devices, and may send image data to any and all of the plurality of rendering devices in order to render images and text. The wireless device 24 may be a wireless computer, a personal data assistant, or a cellular telephone, for example. Furthermore, a display on the wireless device 24 may also be a rendering device within the system 10. The personal computer 22 may be coupled to any and all of the plurality of rendering devices by an appropriate cable connection. The system 10 may be part of a larger networked computer system in which

several personal computers are connected to a central server (not shown) and in which the personal computers share resources, including the plurality of rendering devices.

Individual rendering devices may have different memory capacities. For example the ink jet printer 50 may have a data storage capacity of 64 MegaBytes in RAM, the laser printer 40 may have a storage capacity of 128 MegaBytes in RAM, and the large format printer 60 may have a data storage capacity of 20 GigaBytes in a hard drive. The description that follows will refer to a printing system as an exemplary embodiment of low-memory rendering. However, those of ordinary skill in the art will recognize that similar techniques may be used with rendering devices other than printers.

Figure 1b illustrates a printer 70 and corresponding image data source 20, for example the personal computer 22. The printer 70 includes a communications port 72, a print mechanism 73, a processor 74, a memory 75, and a print application 76. The image data source 20 includes a communications port 101, a data storage device 102, which may be a hard drive, a processor 103, a memory area 104, a user interface 105, which may include a video monitor, keyboard, and pointing device, an operating system 106, a printer driver 107, and an applications program 108. The printer 70 and the image data source 20 may communicate using a local area network cable 110.

The printer 70 operates the print application 76 written in a known printing language such as Hewlett-Packard Graphics Language 2 (HPGL2), which is capable of handling bit maps and vectors, or HP Raster Transfer Language (HPRTL), which is capable of receiving bit map data in rasterized form. The print application 76 converts the print data into a form in which the print mechanism 73 can produce a printed image.

Image data, and in particular image data sent by the image data source 20, may be sent to the printer 70 without the print data source having any knowledge of the memory capacity of the printer 70. The image data so transferred may be layered, and each layer of the image data may be sent from the image data source 20 to the printer 70 as successive digital data files of increasing higher resolution. That is, the image data source 20 may sample the image data at different resolutions, with each such sample comprising a resolution layer, and the successive resolution layers are then sent to the printer 70. The image data sent to a printer 70 will be the same, regardless of the memory capacity of the printer. For example, and referring to Figure 1a, the personal computer 22, as the image data source 20, will send the same data, in the same resolution layers to each of the printers 40, 50, and 60, even though the memory capacity of the printers 40, 50, and 60 is

different. As a result, the format of the image data sent from the image source 20 can remain fixed, regardless of the image data destination.

The system 10 shown in Figure 1a may be used to render images of acceptable quality by rendering a subset of image data corresponding to a background image of the image to be rendered, rendering text and/or vector data of the image to be rendered, and, depending on memory capacity of the rendering device, rendering additional image data corresponding to the background image. To accomplish this low-memory rendering, the data corresponding to the image to be rendered may be divided according to a first rule to produce multiple first data segments. Each of the first data segments may then be divided according to a second rule to provide multiple second data segments. The first rule may generate multiple swaths as the first data segments and the second rule may produce multi-resolution levels for each of the swaths. In the rendering device, each swath is then rendered using a multi-resolution rendering method. In an embodiment, only the multi-resolution data segmentation is performed. The multi-resolution and swath methods will be described below.

Figures 2a – 2c illustrate a conceptual model of multi-resolution coding using frequency domain compression. Such a multi-resolution coding scheme may be used to improve the speed and efficiency of printing when using a low memory printer. The conceptual model shown in Figures 2a - 2b relies on JPEG discrete cosine transformation (DCT) coding. However, other frequency-domain coding schemes may also be used to enhance printing efficiency, including wavelet coding and region-based subband coding.

In Figure 2a, the coding scheme uses JPEG DCT coding for processing 8X8 blocks of pixels from an image bitmap to form an encoded image that may be transmitted to a print device for decoding and printing. The encoding process begins with a DCT step that transforms a two-dimensional block of pixels from the spatial domain to a two-dimensional array of frequency coefficients in the frequency domain. The DCT step decorrelates the 64 image pixels in the 8X8 pixel block and concentrates most of the pixel's energy into coefficients in the top left corner of the frequency array, leaving the remaining pixels with near-zero values. Among the frequency coefficients, the DC coefficient represents the average intensity value of the 64 pixels in the spatial domain. The other coefficients represent spatial features occurring at different frequencies in the 8X8 block of pixels. Within the frequency coefficient array, the lowest frequency coefficients are located in the upper left and the highest frequency coefficients in the

lower right. The DCT step is a lossless operation because, if the coefficients are represented with sufficient accuracy, the 8X8 block of pixels can be recovered exactly.

The next step is quantization, a lossy operation that drives small, nonessential frequency components to zero by scaling each frequency coefficient to the nearest multiple value found in a quantization table. A zig-zag sequence is used to read out the quantized frequency coefficients into a one-dimensional array in preparation for transmission to the print device. This sequence orders the frequency coefficients from lowest to highest, allowing further encoding to be applied for efficient transmission to the print device.

Upon receipt at the print device, such as the printer 70, a decoder in the print device, using the same quantization table as that used in the encoding device, dequantizes the quantized coefficients. An inverse DCT step is then performed to approximately recreate the 8X8 blocks of pixels.

The JPEG DCT coding scheme may be implemented in a hierarchical manner, providing progressive coding with increased spatial resolution between successive stages. Thus, the image to be printed is encoded at multiple resolutions so that lower-resolution versions may be transmitted to the print device and printed without having to decompress the image at its full resolution.

As noted above, other frequency coding schemes may be used to enhance low-memory printing. Wavelet coding uses localized basis functions to break down an image into its essential details. Using short-duration waves, rather than a continuous sinusoid as in DCT coding, wavelet coding can more efficiently represent small features in an image, such as rapid transitions that occur at an edge of an object. In addition, wavelet coding allows for full image encoding, rather than the 8X8 block encoding structure used by DCT transform coding. These advantages allow wavelet coding to provide higher compression ratios for a given image quality.

Yet another coding scheme is region-based subband coding (RBSSC), described in detail in "A region-based subband coding scheme," by Joseph Casas and Luis Torres, which is hereby incorporated by reference.

Figure 2b illustrates the concept of JPEG DCT coding as a solution to low-memory rendering. An initial image to be rendered comprises a background image, vectors, and text. The background image may be divided into 8X8 blocks of pixels. Each of the 8X8 pixel blocks is then subject to frequency transform coding, such as, for example, completing discrete cosine transform and quantization steps. The thus-

transformed 8X8 pixel block is zig-zag scanned to produce a one-dimensional array of transform coefficients, arranged from lowest frequency to highest frequency. Next, the array of transform coefficients is divided into one or more packets, depending on the number of resolution levels or layers desired. For example, if three resolution levels will be used, a first packet comprising the four lowest frequency coefficients is constructed. A second packet comprises the next twelve coefficients. A third packet comprises the final 48 and highest frequency coefficients. If four resolution levels will be used, four packets comprising 1, 3, 12 and 48 coefficients are assembled. Other arrangements of coefficients can be used for more resolution levels.

Once the packets are constructed, for each of the 8X8 pixel blocks, the first resolution level is sent to the rendering device (e.g., a display, printer, facsimile). Next, any vector and text data are sent to the rendering device. Then, subsequent resolution layers are sent to the rendering device. If a memory capacity of the rendering device is reached upon receipt of the first resolution level and the vector and text data, the rendering device may still render an acceptable image. If the memory capacity is not reached after receipt of the first resolution level and the vector and text data, the rendering device may receive the subsequent resolution level background image data, and may combine the data to produce a refined background image.

Figure 2c shows an inverse transform operation at the rendering device. In the illustrated example, the first and second of three resolution levels have been received at the rendering device before the memory capacity of the rendering device is reached. That is, only the first 16 lowest frequency transform coefficients are received at the rendering device as shown. The received transform coefficients are arranged in an 8X8 block, with zeros representing non-received coefficients. The coefficients are then decoded using inverse quantization and inverse DCT steps to produce an approximation of the original 8X8 pixel block.

The processes shown in Figure 2b and 2c may be completed for an entire original image. Alternatively, the original image may be deconstructed into one or more sub-images, or swaths, and the coding and immerse coding processes may be completed fro each such swaths. Use of swaths is particularly applicable to printing operations, especially printing using large scale plotters and inkjet printers. Deconstruction of an image into swaths will be described below with reference to Figure 4.

Figures 3a – 3c illustrate the effect of downsampling (which is explained in detail in U.S. Patent Application, Serial Number __/___,___, entitled "Multi-Resolution

Printing," which is hereby incorporated by reference) and frequency coding on the image rendering process. In each of Figures 3a – 3c, the horizontal axis represents the number of bits or coefficients (data) that are sent to a rendering device, such as the printer 70. The vertical axis represents the Human Visual System Picture Quality. A first, or minimum quality threshold may be specified to ensure the print quality is acceptable. Unacceptable print quality may occur when less than the entire bitmap can be printed, resulting, for example, in white stripes in the printed image due to non-receipt of image data. A situation in which no white stripes are visible may be referred to as the No Objection Quality (NOQ) level. After the NOQ level is achieved, the rate at which image quality increases (to an Intermediate Quality (IQ) level and thence to a Maximum Quality (MQ) level) depends on how the bitmap is sent to the rendering device.

Referring to Figure 3a, a printing operation with no multi-resolution coding and no downsampling is shown. In this case, the NOQ and MQ levels are obtained at the same time, specifically when the entire image bitmap is received at the printer 70. Any image data (bitmap) transmission with fewer bits will result in objectionable quality levels.

Figure 3b shows the effect of downsampling. In this case, once the first (lowest) resolution set of data is received at the printer 70, the image may be rendered without any white stripes. Thus, the NOQ level is achieved when the lowest resolution layer is received at the printer 70. Subsequent to reception of the lowest resolution layer, additional resolution layers received at the printer 70 provide increasing image quality up to the MQ level.

Figure 3c shows the effect of frequency domain coding. In this case, NOQ is reached much sooner due to the compression (e.g., JPEG DCT or other transform domain compression). After the NOQ level is achieved, image quality increases very rapidly to close to the MQ level. At a point in the bitmap transmission (designated IQ) the image quality is as good as can be achieved (because of the inherent lossy nature of the quantization algorithms used in transform coding), and a very high quality image is possible with only the IQ bits received at the printer 70.

Figure 4 illustrates a conceptual model of swath construction 300 that may be used for multi-resolution printing using low-memory printers. The image data source (represented in Figure 4 as the personal computer 22) is coupled to a plurality of printers 80_i. Each of the printers 80_i may have a different memory capacity. Some of the printers 80_i may store print data (including image data) in RAM. Other printers 80_i may store

print data in a hard drive, for example. The personal computer 22 may divide, or deconstruct, an image 310 to be printed into a plurality of swaths, with each swath comprising a fixed "height" of the image. Thus, the image 310 may be deconstructed into swaths 311 - N. For example, the image 310 may be deconstructed into 10 swaths, each representing a one-inch "height" of the image 310. The personal computer 22 may then send each of the swaths 311 - N to the printers 80_i in a successive fashion. That is, the personal computer 22 may send the swath 311 to the printers 80_i, followed by the swath 312, and so on until all the swaths 311 - N are sent.

In an embodiment, each of the printers 80_i will receive the swaths 311 - N and will attempt to store the swaths in memory. However, if a memory capacity of a particular printer 80_i is reached before all the swaths 311 - N are received and stored, that printer 80_i may begin printing the stored swaths, thereby freeing memory to store the remaining swaths. In an alternative embodiment, each of the printers 80_i will immediately begin printing a received swath once the received swath is stored in memory. The thus-printed swath may then be discarded from memory. The process continues until all swaths are received, stored, printed, and discarded.

In another embodiment, the concepts illustrated in Figures 2a –2c and 3c may be combined with the swath construction 300. In this embodiment, the image data source 20 deconstructs an image to be printed into a plurality of swaths. Then, for each such swath, the image data source 20 completes a frequency transform operation, such as JPEG DCT coding, for example. Each swath of the image is then transferred, as a series of increasingly higher resolution layers, to a printer. The printer stores each of the swath resolution layers until a memory capacity of the printer is reached. When the memory capacity is reached, the transferred data are combined, and a swath is printed. The image data for the thus-printed swath is then discarded from memory. The image data source 20 then sends the next successive swath to the printer, again in a frequency compressed coding scheme. This process continues until the entire image is rendered by the printer.

In the description provided above with respect to Figure 4, only background image data was frequency encoded prior to transfer from the image data source 20 to the printer. However, as also noted above, an image to be rendered may include vector data and text data, for example. In the event that vector data and text data accompany the image data, such vector data and text data may be transferred to the rendering device after at least a minimum resolution layer of the background image data are transferred.

Alternatively, the vector data and the text data may be transferred before the background image data is transferred.

Figure 5 illustrates schematically an image data file 350 that may be transmitted from the image data source 20 to a rendering device, such as the printers 80_i of Figure 4. The file 350 includes a number of image data resolution files, such as files 360, 370, 380 and 390. Each of the files 360, 370, 380 and 390 in turn comprises a number of files. For example, the file 360 comprises a level 1 data header file 361, which indicates that data related to the first resolution layer will follow; a data field 362 comprising transform coefficients for the first resolution layer; a vector data field 363 comprising any vector data associated with the image; and a text data field 364 comprising text data for the image. The vector data in the vector data field 363 and the text data in the text data field 364 may, when printed, overlay the background image data. Subsequent resolution layer files may be constructed in a manner similar to that of the file 310.

Returning to Figure 4, in the illustrated system 300, an image to be printed may be deconstructed into the swaths 311 - N, assuming that a particular printer 80_i will be capable of storing all print data associated with a particular swath. That is, the image data source 20 may have prior knowledge of the minimum memory of attached printers, and the image data source 20, when constructing the swaths, will structure the swaths such that each of the printers 80_i is capable of storing all data related to the particular swath. In an alternative embodiment, the image data source 20 has no prior knowledge of printer memory capacity, and so constructs the swaths according to a set rule. The set rule may be based on average memory in most common printers, a lower limit on a range of available printer memory, or other rules.

The above-described embodiments of low-memory rendering methods and devices maximize memory usage of a rendering device. In particular, the embodiments allow the rendering device to render a background image having an acceptable quality level, and to also render text and vector data. The quality of the background image may be improved for rendering devices having larger memory capabilities.

Figure 6 is a flowchart illustrating a process 400 that may be carried out to provide multi-resolution printing with low-memory printers. The process 400 may be carried out using the system 10 shown in Figure 1a, with an image being deconstructed into swaths according to Figure 4 and layers within swaths according to Figures 2a – 2c.

The process 400 begins with start block 405. In block 410, the personal computer 22 receives an image to be printed, and deconstructs the image into N swaths. The image

to be printed may comprise image data, vector data and text data, with the vector and text data overlaying the image data, for example. Alternatively, some or all of the vector data and/or some or all of the text data may be included in an area of the image that does not overlay the image data. In deconstructing the image to be printed into N swaths, the personal computer 22, executing the process block 410, may use a height of the image to be printed to determine the "height" of each of the N swaths. Alternatively, the personal computer 22 may determine a data density of the image to be printed, and may adjust the "heights" of each of the N swaths according to a nominal or a known memory capacity of printer that may print the image to be printed. The personal computer 22 may determine the data density by, for example, scanning the image, reading data density information from a file accompanying the image to be printed, or by other means. When setting the swath "height," the personal computer need not make the "heights" of each of the N swaths equal.

In select swath block 415, the personal computer 22 selects the i^{th} swath, starting with the first swath of the image to be printed. The first swath may typically be a swath located at a top of the image to be printed. In multi-resolution coding block 420, the personal computer 22 executes a sub-routine 420 to transform the background image data of the i^{th} swath into the frequency domain. Such a frequency encoding routine is described in detail with reference to Figure 8.

In send data block 425, the personal computer 22 transfers print data associated with the i^{th} swath to one or more printers that may be coupled to the personal computer 22. In an embodiment, the print data associated with the i^{th} swath may be transferred after all resolution layers are constructed. Alternatively, the print data associated with the i^{th} swath may be transferred one resolution layer at a time. If the i^{th} swath includes only one resolution layer, then the print data associated with the i^{th} swath may be transferred as soon as the N swaths are created. Figure 9 shows the send data subroutine 425 in more detail.

In increment counter block 430, the personal computer 22 may increment a counter to advance the swath number by one increment. In block 435, the personal computer 22 determines if the thus-incremented value of i equals N. If the values equal, the process 400 proceeds to block 440 and ends. Otherwise, the process 400 returns to block 415, and the next swath is selected.

Figure 7 is a flowchart illustrating the subroutine 410 for dividing the image to be printed into swaths. In block 411, the personal computer 22 determines a size of the

image to be printed. In an embodiment, the personal computer 22 determines overall dimensions (height and width in inches, for example) of the image to be printed, as the image will appear when rendered onto a print medium. The personal computer 22 may also determine data density of the image to be printed (for example, the number of pixels in the image, vector data and text data). In block 412, the personal computer 22 determines if any printer that is designated to print the image has provided memory capacity information. If memory capacity information has been provided, the subroutine 410 may proceed to block 413, and select a swath "height" based on the provided memory capacity information. The subroutine 410 then ends, and processing returns to the main routine 400 for multi-resolution printing.

In block 412, if the personal computer 22 determines that memory capacity information has not been provided, then processing may proceed to block 414, and the swath "height" may be selected based on a pre-defined rule. For example, the pre-defined rule could specify that each swath should have a "height" corresponding to one (1) inch of vertical height of the image to be printed. The subroutine 410 then ends.

As noted above, each of the N swaths determined in block 410 may be further resolved into a number of resolution layers. Alternatively, the entire image to be printed may be resolved into a number of resolution layers, and no swaths would then be constructed.

Figure 8 illustrates the frequency coding sub-routine 420 that may be used to encode an entire image bitmap, or to encode each swath of the image. The sub-routine 420 begins by dividing the image (or resolution layer or swath) into 8X8 pixel blocks (block 490). In block 492, each of the 8X8 pixel blocks is transformed into the frequency domain by using a JPEG DCT coding scheme. Next, in block 494, each of the transformed 8X8 pixel blocks is quantized using a JPEG standard quantization table. In block 496, the quantized frequency coefficients are read out into a one-dimensional array in preparation for transmission from the image data source 20. In block 498, the array of transform coefficients is packetized according to the number of resolution levels desired. The sub-routine 420 then ends, block 499, and processing returns to block 425.

Figure 9 is a flowchart that illustrates the send data sub-routine 425. In block 500, a first level header data is generated, containing data specifying that a multi-resolution format will follow, and specifying the first resolution level (i.e., resolution layer 1). In block 505, the first level image data is sent from the personal computer 22, comprising the first level of frequency coefficients. In block 510, vector data is sent in a vector field.

In block 515, text data describing any text additions to the image is sent in a text data field. In block 520 second level header data is sent indicating second resolution level image data (i.e., frequency coefficients) will follow. In block 525, the second resolution level image data, at a higher resolution than the first resolution level image data is sent. In block 530, a third level header data is sent indicating third resolution level image data will follow, and in block 535, third resolution level image data is sent, being of a higher resolution than the first level or second level image data. Successive levels of image data, each preceded by a header data are sent until the highest resolution level image data is sent.

Successive levels of resolution of image data may be sent, up the maximum resolution obtainable from the source image data. Therefore, the process steps through sending levels 1 - M of image data and stops, when the maximum resolution permitted by the source image data has been reached.

The above-described embodiments allow rendering of high resolution vector and text data, on a rendering device having a limited memory area, where a background image is rendered with a resolution that is limited by an available memory capacity or data storage capacity of the rendering device. For example, an architect's drawing may comprise an aerial photograph of a land site, together with an architectural drawing, specified in vector data, plus some text data overlaying the aerial image. The resolution of rendering of the aerial image may be limited by a printer's memory, but the resolution of the architectural drawing and text data are not limited by the memory or data storage capacity of the printer device, but are always printed in very high resolution, for example using the HPGL2 vector graphics language.

The same image data file sent to a different printer or rendering device having a higher memory capacity and/or data storage capacity, may provide a higher resolution background image data, and with vector and text data information at the same resolution as the lower memory capacity/data storage capacity printer device.

In the claims:

1. A method for rendering an image comprising an image data file, the image data file including vector data and text data, using multi-resolution frequency coding, the method, comprising:

performing (492) a frequency transform on image data in the image data file, whereby frequency transformed coefficients are produced;

quantizing (494) the frequency transformed coefficients;

scanning (496) the quantized frequency transformed coefficients, wherein the scanned, quantized and frequency transformed coefficients comprise an array of transform coefficients from lowest to highest frequency;

packetizing (498) the transform coefficients into one or more resolution levels;

sending (505) at least a lowest resolution level to a rendering device; and

sending the vector data (510) and the text data (515) to the rendering device.

2. The method of claim 1, further comprising:

dividing (410) the image data file into one or more swaths, wherein each of the one or more swaths comprises a subset of data from the image data file, the dividing step, comprising:

determining a data density quantity for the image data file, and

constructing the one or more swaths to include a specified height of the image data file; and

successively providing (425) each of the plurality swaths to the rendering device.

3. The method of claim 2, wherein each of the plurality of swaths is subjected to the multi-resolution frequency coding.

4. The method of claim 2, wherein the rendering device is a printer (70).

5. The method of claim 1, wherein the rendering device is one of a display (30) of a personal computer (22), a display (24) of a mobile electronic device (20), and a facsimile machine.

6. The method of claim 1, wherein the vector data and the text data is sent to the rendering device after sending the lowest resolution level.

7. The method of claim 6, further comprising:

sending one or more higher resolution levels to the rendering device after sending the vector data and the text data;

sending one or more higher resolution levels after sending the lowest resolution level.

8. A method for low-memory rendering of an image, comprising:

first processing (400) the image to be rendered according to a first rule, whereby first subdivision segments are produced, and wherein the image comprises an image data file;

second processing (420) one or more of the first subdivision segments according to a second rule, whereby multi-resolution layers are produced; and

sending (425) the multi-resolution layers and the segments to a rendering device, wherein the first rule constructs a sequence of swaths (310), the subdivision segments comprising the swaths, wherein the second rule provides frequency domain encoding of one or more of the swaths to provide the multi-resolution layers, and wherein the multi-resolution layers are encoded using discrete cosine transform (DCT) coding, comprising:

dividing the image into 8X8 pixel blocks (490);

performing DCT (492) and quantization (494) of the pixel blocks to produce transform coefficients;

scanning (496) the transform coefficients; and

packetizing (498) the scanned transform coefficients to produce the multi-resolution layers.

9. The method of claim 8, wherein each of the swaths comprises a subset of data from the image to be rendered, the dividing step, comprising:

determining (411) a data density quantity for the image data file, and

constructing (414) the one or more swaths to include a specified height of the image to be printed.

10. A computer-readable medium comprising programming for low-memory rendering, the programming used for performing image processing steps, comprising:

performing (492) a frequency transform on image data related to an image, whereby frequency transformed coefficients are produced;

quantizing (494) the frequency transformed coefficients;

scanning (496) the quantized frequency transformed coefficients, wherein the scanned, quantized and frequency transformed coefficient comprises an array of transform coefficients from lowest to highest frequency;

packetizing (498) the transform coefficients into one or more resolution layers;

sending at (505) least a lowest resolution level to a rendering device;

sending text (515) and vector (510) data after sending the lowest resolution level; and

sending (525, 535) one or more higher resolution levels.

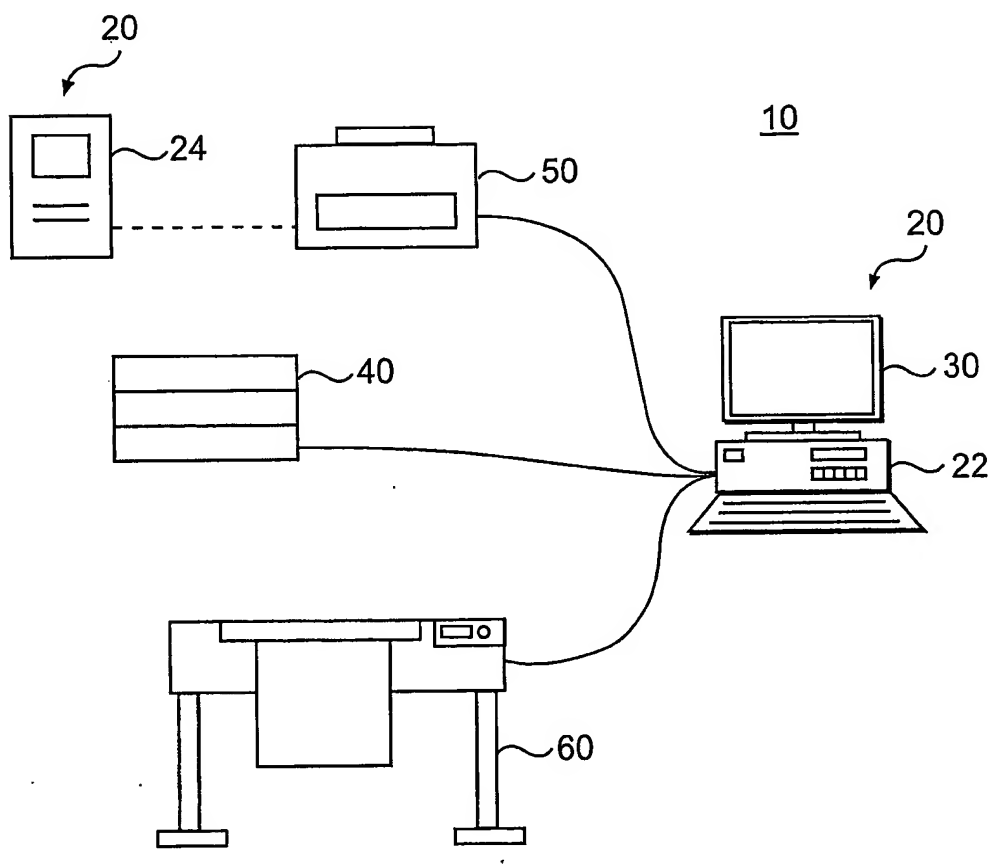
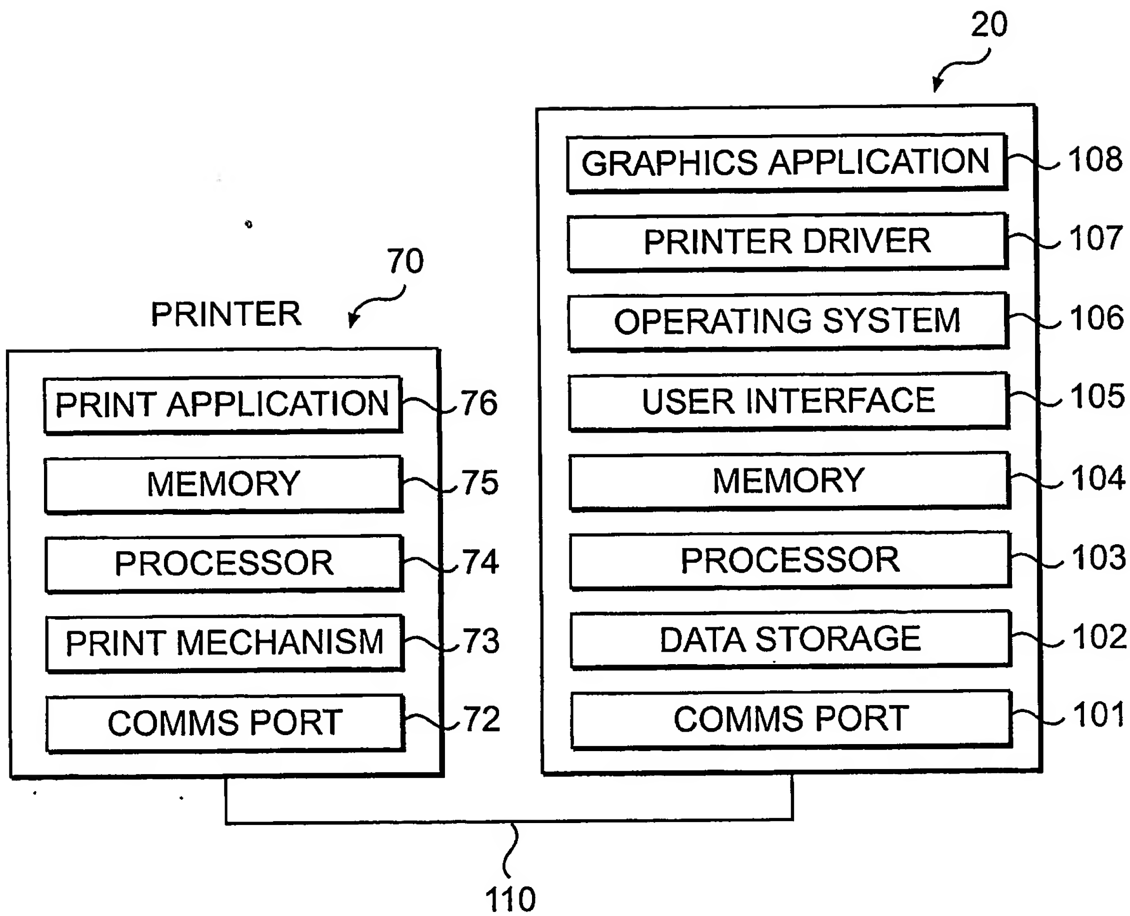


FIG. 1A



20
GRAPHICS APPLICATION
108
PRINTER DRIVER
107
OPERATING SYSTEM
106
USER INTERFACE
105
MEMORY
104
PROCESSOR
103
DATA STORAGE
102
COMMS PORT
101
70
PRINTER
PRINT APPLICATION
76
MEMORY
75
PROCESSOR
74
PRINT MECHANISM
73
COMMS PORT
72
110

FIG. 1B

0	0	0	0	0	0	0	0
0	32	32	32	32	32	32	0
0	32	64	64	64	64	32	0
0	32	64	128	128	64	32	0
0	32	64	128	128	64	32	0
0	32	64	64	64	64	32	0
0	32	32	32	32	32	32	0
0	0	0	0	0	0	0	0

DCT

-784	0	-164	0	-16	0	-19	0
0	0	0	0	0	0	0	0
-164	0	137	0	-21	0	11	0
0	0	0	0	0	0	0	0
-16	0	-21	0	48	0	-9	0
0	0	0	0	0	0	0	0
-19	0	11	0	-9	0	23	0
0	0	0	0	0	0	0	0

QUANTIZATION

-49	0	-16	0	-1	0	0	0
0	0	0	0	0	0	0	0
-12	0	9	0	-1	0	0	0
0	0	0	0	0	0	0	0
-1	0	-1	0	1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

-49 0 0 -12 . . . 0 0 0 0 EOB

→ TRANSFER

FIG. 2A

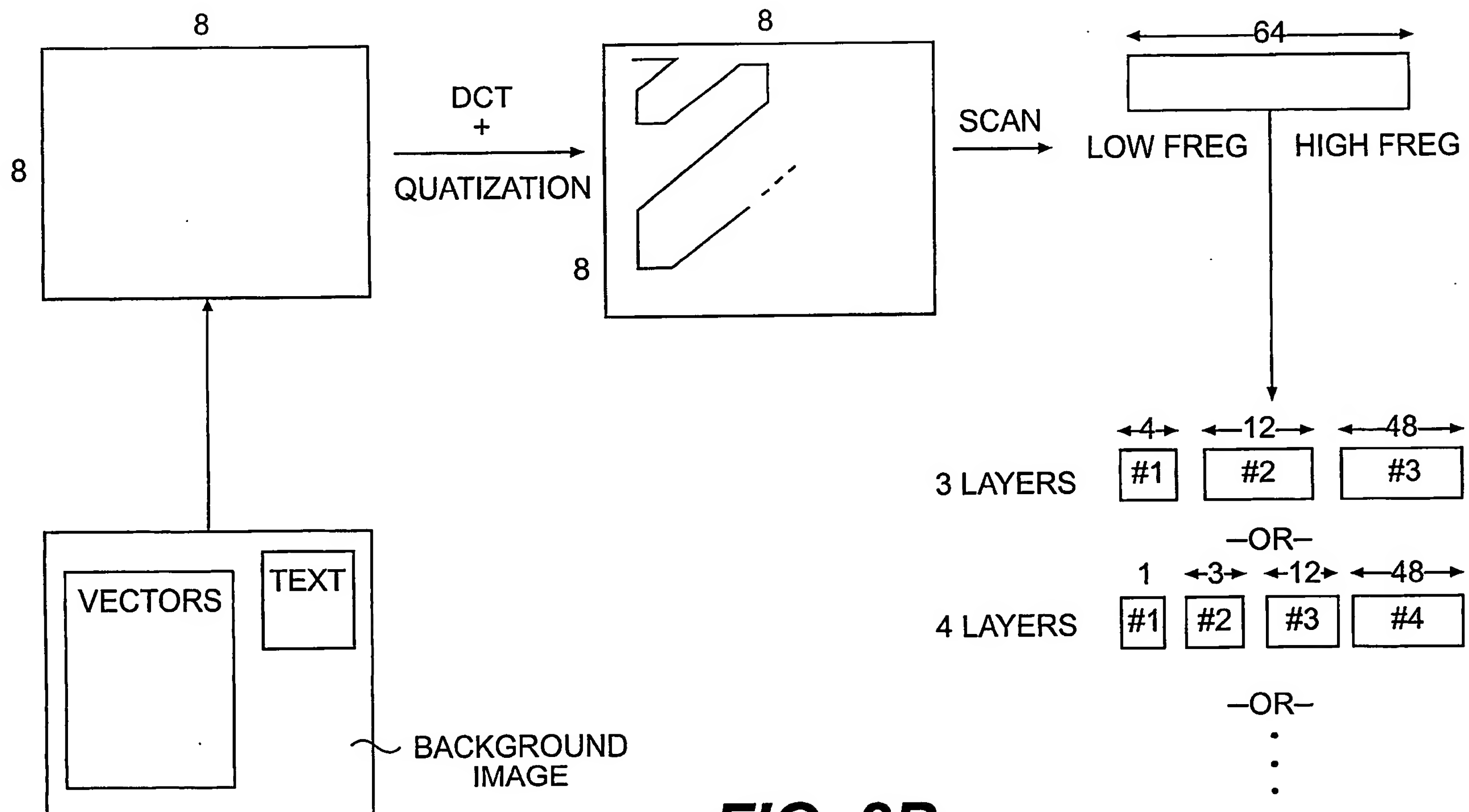

8
8
DCT
+
QUATIZATION
8
8
SCAN
64
LOW FREG
HIGH FREG
4
12
48
3 LAYERS
#1
#2
#3
—OR—
1
3
12
48
4 LAYERS
#1
#2
#3
#4
—OR—
VECTORS
TEXT
BACKGROUND
IMAGE

FIG. 2B

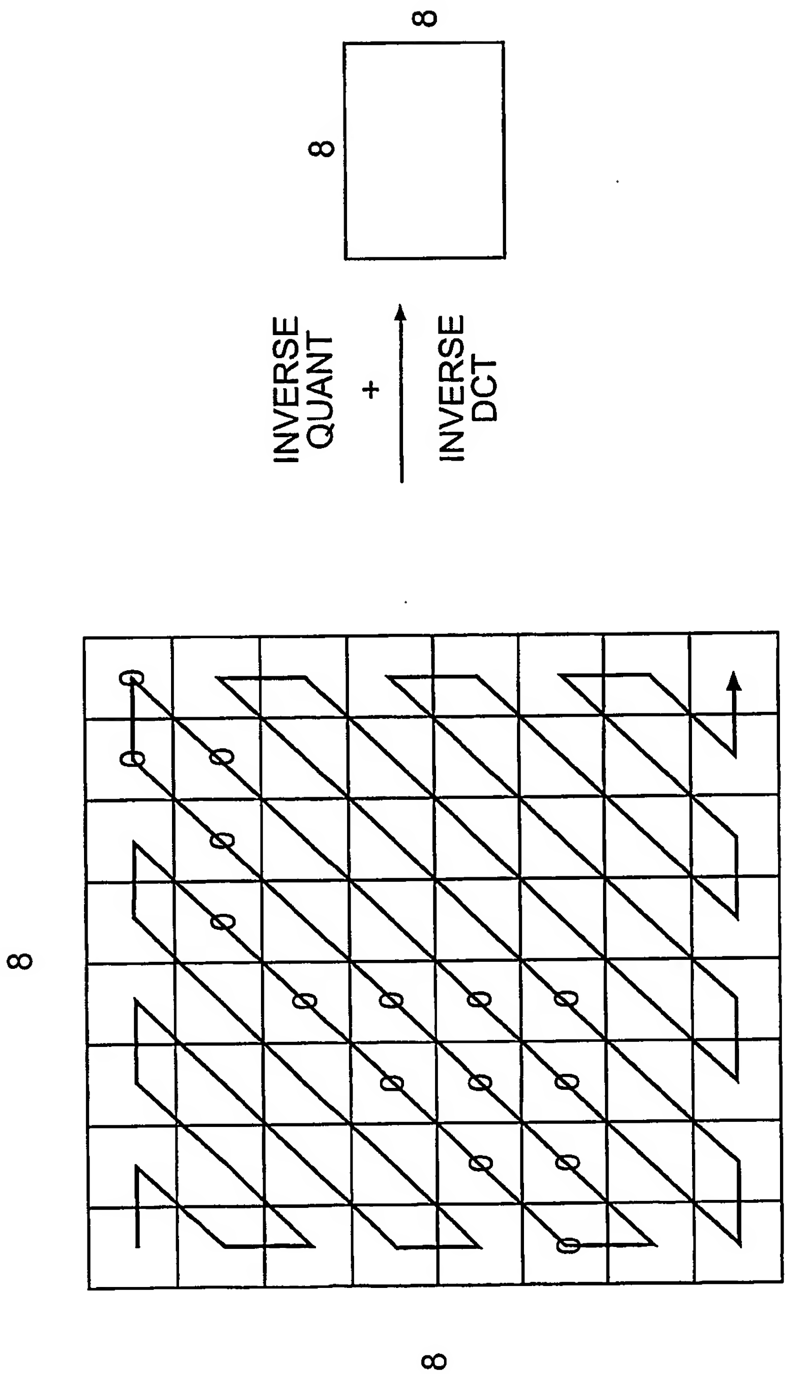


FIG. 2C

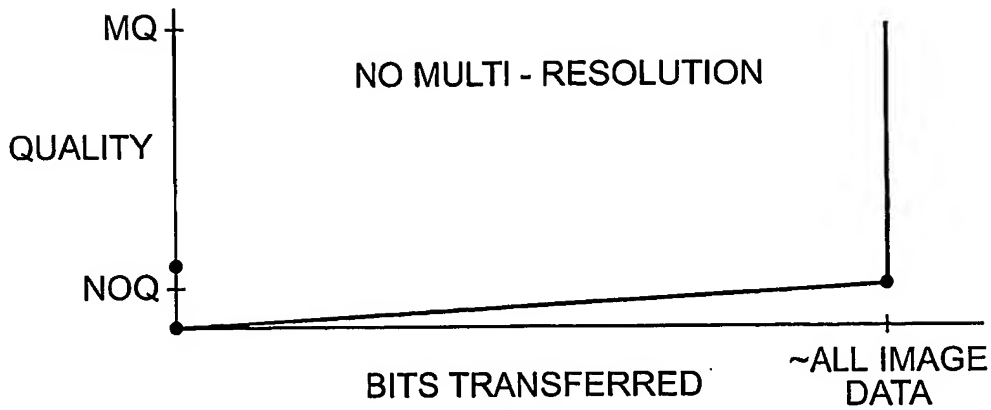


FIG. 3A

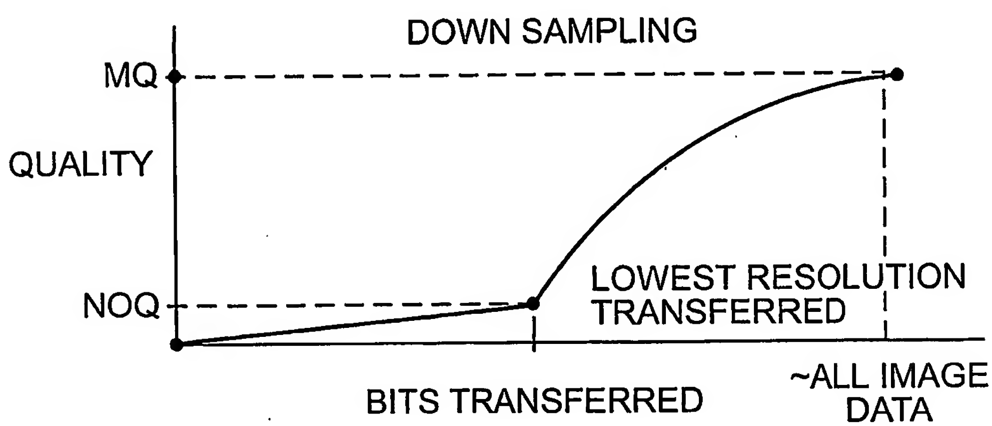


FIG. 3B

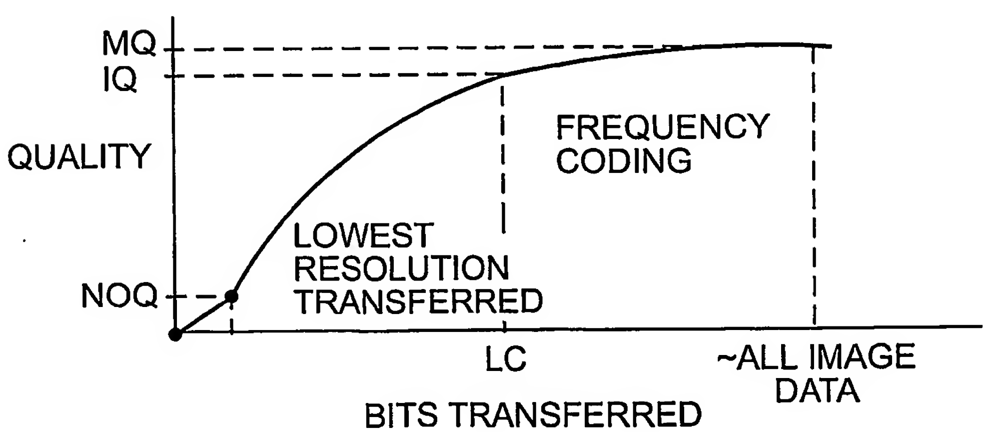


FIG. 3C

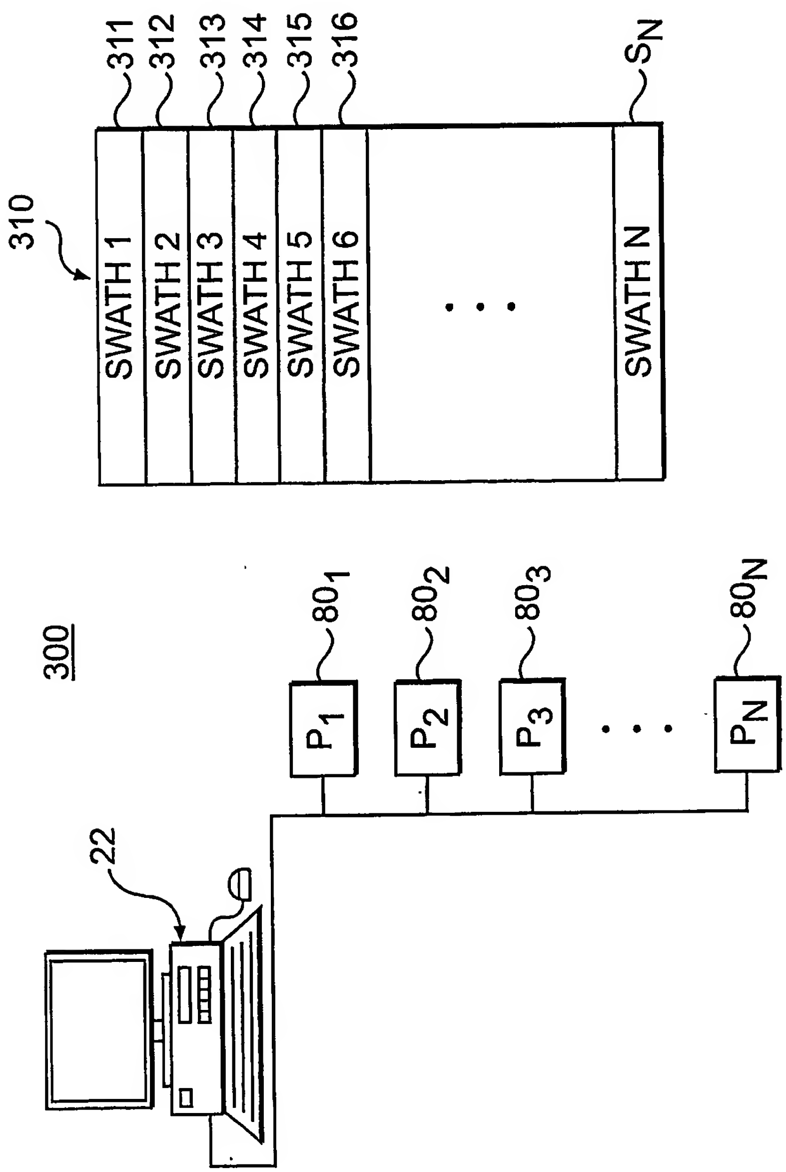

300
22
P_1
P_2
P_3
P_N
80_1
80_2
80_3
80_N
310
SWATH 1
SWATH 2
SWATH 3
SWATH 4
SWATH 5
SWATH 6
SWATH N
311
312
313
314
315
316
S_N

FIG. 4

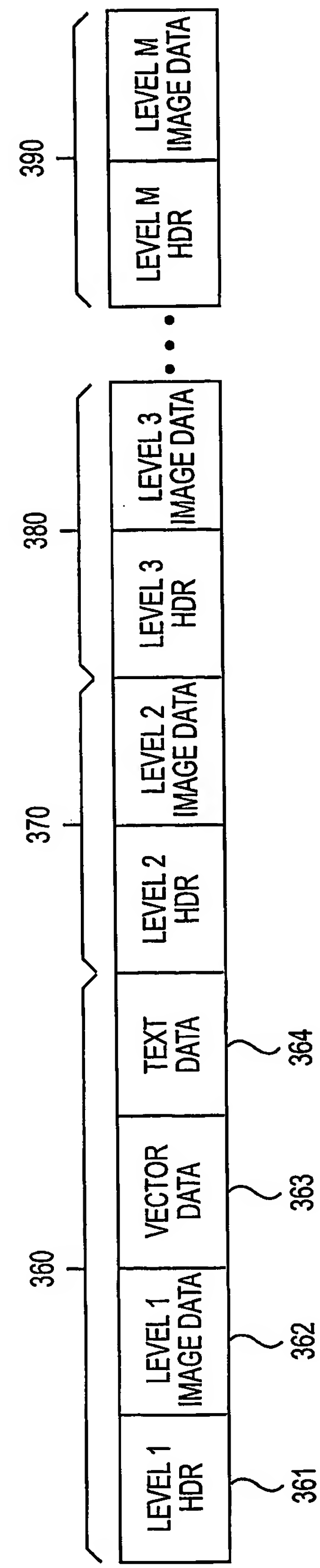

360
370
380
390
LEVEL 1 HDR
LEVEL 1 IMAGE DATA
VECTOR DATA
TEXT DATA
LEVEL 2 HDR
LEVEL 2 IMAGE DATA
LEVEL 3 HDR
LEVEL 3 IMAGE DATA
LEVEL M HDR
LEVEL M IMAGE DATA
361
362
363
364

FIG. 5

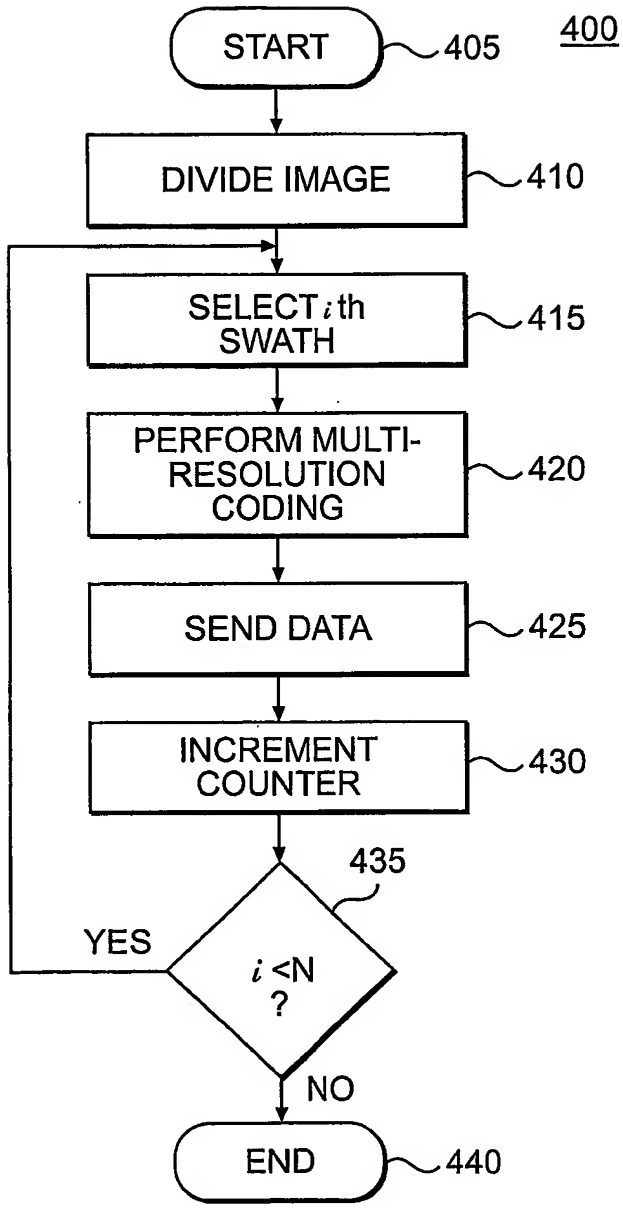

400
START
405
DIVIDE IMAGE
410
SELECT i th SWATH
415
PERFORM MULTI-RESOLUTION CODING
420
SEND DATA
425
INCREMENT COUNTER
430
435
YES
i <N ?
NO
END
440

FIG. 6

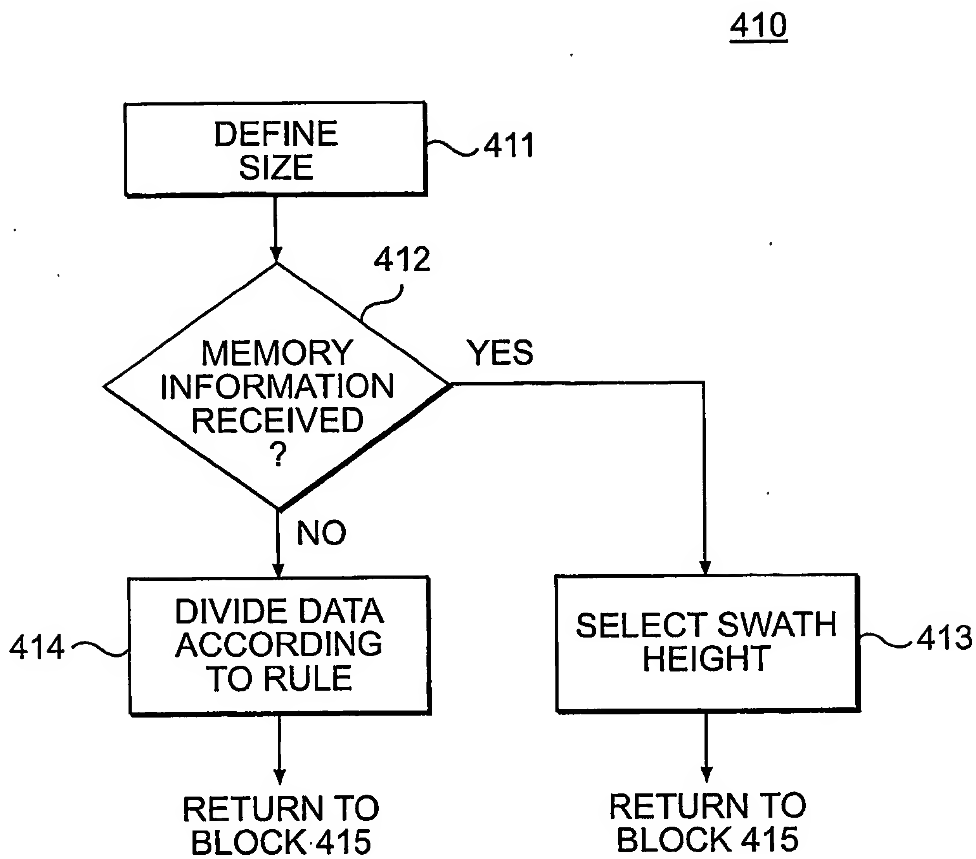

410
DEFINE SIZE
411
412
MEMORY INFORMATION RECEIVED ?
YES
NO
DIVIDE DATA ACCORDING TO RULE
414
SELECT SWATH HEIGHT
413
RETURN TO BLOCK 415
RETURN TO BLOCK 415

FIG. 7

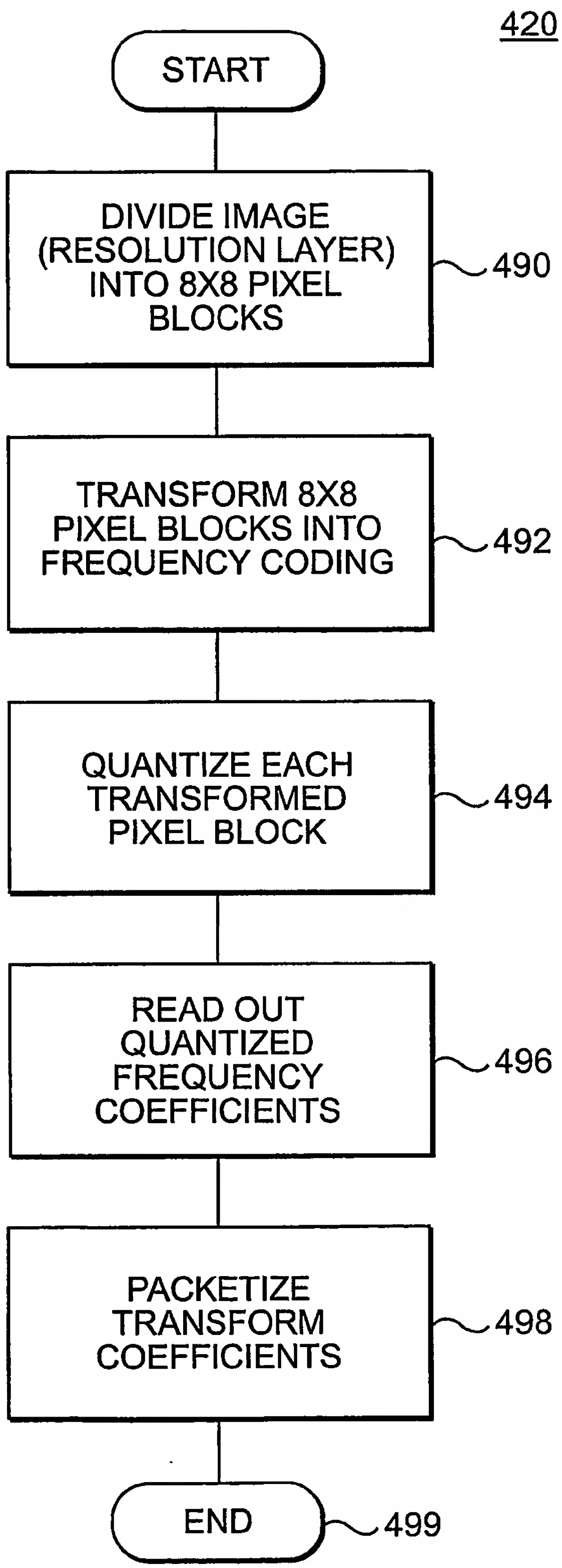

420
START
DIVIDE IMAGE (RESOLUTION LAYER) INTO 8X8 PIXEL BLOCKS
490
TRANSFORM 8X8 PIXEL BLOCKS INTO FREQUENCY CODING
492
QUANTIZE EACH TRANSFORMED PIXEL BLOCK
494
READ OUT QUANTIZED FREQUENCY COEFFICIENTS
496
PACKETIZE TRANSFORM COEFFICIENTS
498
END
499

FIG. 8

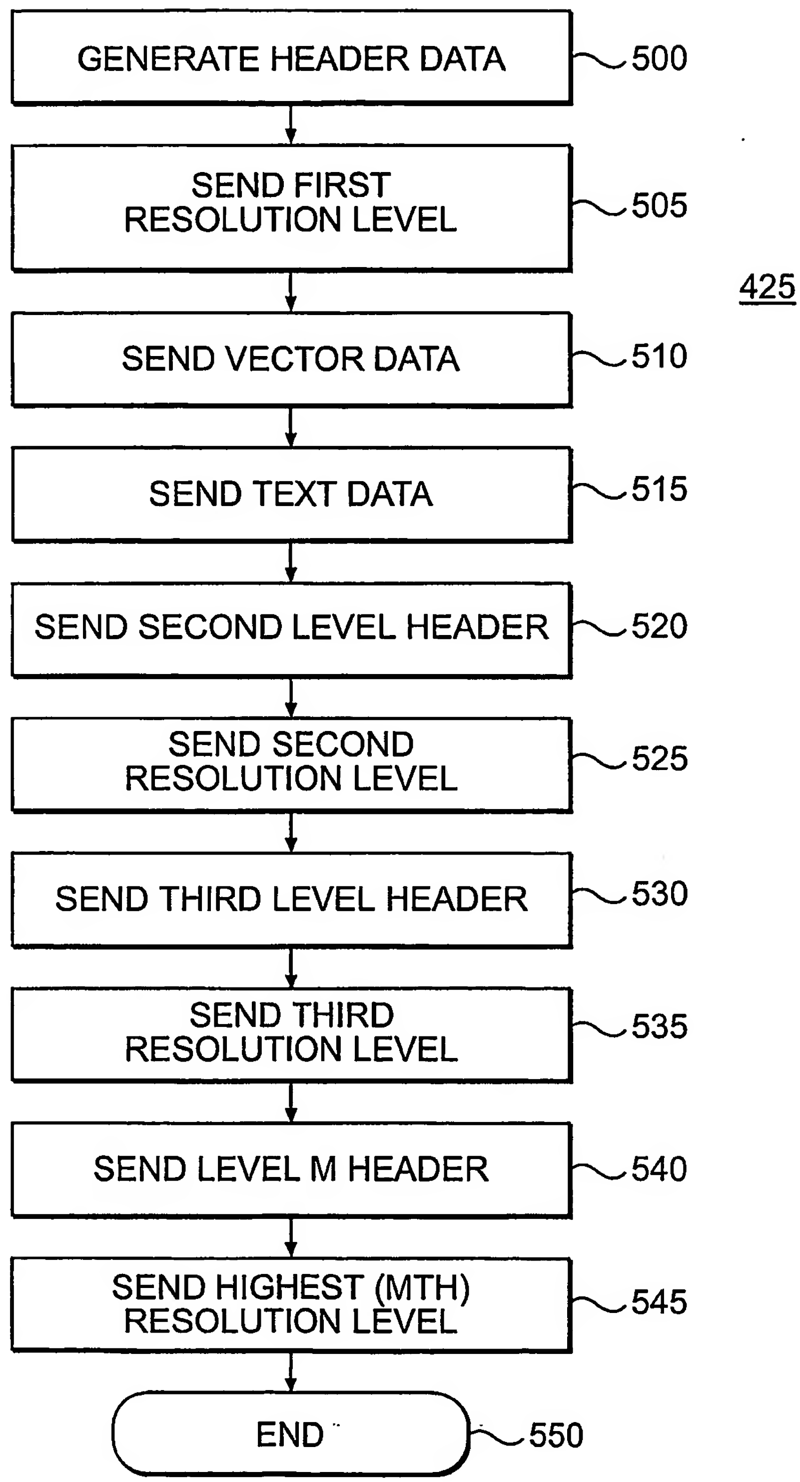

GENERATE HEADER DATA
500
SEND FIRST RESOLUTION LEVEL
505
425
SEND VECTOR DATA
510
SEND TEXT DATA
515
SEND SECOND LEVEL HEADER
520
SEND SECOND RESOLUTION LEVEL
525
SEND THIRD LEVEL HEADER
530
SEND THIRD RESOLUTION LEVEL
535
SEND LEVEL M HEADER
540
SEND HIGHEST (MTH) RESOLUTION LEVEL
545
END
550

FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/34876

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N1/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 754 192 A (SUGAYA AKIO) 19 May 1998 (1998-05-19) column 10, line 19-30	1,4,5,8, 10
A	PENNEBAKER & MITCHELL: "JPEG Still Image Data Compresion Standard" 1993 , VAN NOSTRAND REINHOLD , NEW YORK XP002233886 page 81-96	1,8,10
A	US 5 758 043 A (TAKAYAMA MASAYUKI ET AL) 26 May 1998 (1998-05-26) column 1, line 37 -column 2, line 17; figures 7-10	2,9

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 March 2003	19/03/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hardell, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/34876

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
E	EP 1 253 548 A (HEWLETT PACKARD CO) 30 October 2002 (2002-10-30) cited in the application the whole document -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 02/34876

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5754192 A	19-05-1998	JP 3295107 B2	24-06-2002
		JP 5035857 A	12-02-1993
		DE 69230161 D1	25-11-1999
		DE 69230161 T2	13-04-2000
		EP 0526096 A2	03-02-1993
US 5758043 A	26-05-1998	JP 8077330 A	22-03-1996
EP 1253548 A	30-10-2002	EP 1253548 A1	30-10-2002
		US 2002186383 A1	12-12-2002